The CEOS Constellation for Land Surface Imaging

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CEOS Land Surface Imaging Constellation Study Team

Committee on Earth Observation Satellites (CEOS)

- CEOS is an international organization charged with coordinating international civil spaceborne missions designed to observe and study the Earth.
- CEOS Membership
  - 28 Members, most of which are space agencies.
  - 20 Associates, which primarily are national and international organizations with interests in the use of space acquired Earth observation data.
- CEOS is recognized as the major international forum for the coordination of Earth observation satellite programs and for the interaction of these programs with users of satellite data worldwide.
- CEOS is the "space arm" of Global Earth Observation System of Systems (GEOSS).

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The CEOS Constellations Concept

- CEOS Constellations concept is new and still evolving.
- It might best be described as a new CEOS process designed -
  - To enhance effective planning and development of future earth observing systems by maximizing advantages of international collaboration without eroding the independence of individual agencies.
  - To increase the effectiveness with which international assets, including both space and ground segments, can be brought to bear on scientific problems and to meet a wide range of societal needs.
- Fundamental concept is to extract clear requirements from target user communities and translate those requirements into "standards," which can serve as guidance in the development of future systems and against which future proposed Earth observing systems can be assessed.

CEOS Constellations

- Potentially, there are many conceivable constellations.
- CEOS has proposed 4 initial prototype virtual constellations.
  - Ocean Surface Topography
  - Precipitation
  - Atmospheric Chemistry
  - Land Surface Imaging
- The USGS has been assigned responsibility for leading the Land Surface Imaging Constellation Study.
- A Study Team with members from many international space agencies, as well as the land remote sensing user community, has been established to conduct the LSI Constellation Study.

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LSI Constellation Study Team Members

- CEOS Agency Members
  - G. Bryan Bailey - Co-Chair (USGS)
  - V. Jayaraman - Co-Chair (ISRO)
  - Herve JeanJean (CNES)
  - João Vianei (INPE)
  - Michael Berger (ESA)
  - Daniel DeLisle (CSA)
  - Anna Medico (CONAE)
  - Takeo Tadona (JAXA)
  - Kevin Gallo (NOAA)
  - Chris Blackerby (NASA)
  - Yonghong Zhang (NRSCC)
- User Community Members
  - Alan Belward (JRC)
  - Brad Reed (USGS)
  - Mike Abrams (JPL)
  - Yasuchi Yamaguchi (Nagoya U.)
  - Stuart Marsh (BGS)
- CEOS WG Members
  - Steve Ungar – WGCV (NASA)
  - Greg Stensaas – WGCV (USGS)
  - Jean-Pierre Antikidis – WGISS (CNES)

Goal and Objectives of the LSI Constellation

- Fundamental Goal or Mission
  - "The Land Surface Imaging Constellation seeks to promote the efficient, effective, and comprehensive collection, distribution, and application of space-acquired image data of the global land surface, especially to meet societal needs of the global population, such as those addressed by the Group on Earth Observations (GEO) societal benefit areas."
- Primary Objectives
  - Define characteristics that describe optimal capabilities (and policies) that can become guidelines (or ***standards***) in the development and operation of ***future*** LSI systems.
  - Address current and near-term problems and issues facing the land remote sensing community today.
    - working more cooperatively in the operation of existing systems.
    - realize tangible benefits to society through application of LSI data.

Methodology and Scope

- Methodology focuses on definition and conduct of a series of Constellation studies and activities.
  - Carried out or directed by the LSI Constellation Study Team
  - Result in the definition of standards for optimal future systems
  - Also address shorter-term problems and issues
- In terms of scope, studies leading to the definition of standards for a LSI Constellation will be based on a compilation of representative user requirements and will examine at least three fundamental areas.
  - Space Segments
  - Ground Systems
  - Policies and Plans

2007 Goals, Objectives, and Accomplishments

- 2007 LSI Constellation studies placed heavy emphasis on mid-resolution land surface imaging systems.
- Three primary goals were identified for 2007.
  - Establish agreement(s), among space agencies currently operating mid-resolution land surfacing imaging satellite systems, to cooperate more closely together to operate those assets as a real prototype Land Surface Imaging Constellation.
  - Develop preliminary standards for a mid-resolution Land Surface Imaging Constellation.
  - Meaningfully contribute to the production of a fundamental climate data record (FCDR).
- None of the three goals were fully accomplished, but important progress was made toward achieving each of them.

Agreement for a *Real* Prototype Constellation

- A "***Declaration of Intent for Cooperation on Mid-Resolution Satellite Systems***" in which space agencies resolve to seek ways to cooperate more fully in the operation of their existing mid-resolution land surface imaging satellite systems was signed by **seven** of eight agencies that operate such systems.
- Three additional agreements that add specificity and detail for cooperation in specified areas were drafted and currently ***are under review by the agencies.***
  - Enhanced user access to data
  - Data acquisition
  - Ground segment operations
- Detailed agreements are based on user recommendations for improved cooperation, and they seek a balance between what users may desire and what space agencies realistically can accommodate.

User Recommendations for Increased Cooperation

- Enhanced User Access to Data
  - Create and maintain a common website.
    - Information about all currently operating LSI mid-resolution satellite systems
    - Characteristics of the data they collect
    - Links to search & order tools for those systems
  - Establish a clearinghouse for free data offered by operators of mid-resolution systems and work to increase amount of free data available.
  - Develop, and provide free access to, "bundles" of mid-resolution LSI data collected over common sites by agency systems.
- Data Acquisition
  - Establish coordinated and complementary data acquisition strategies.
    - Optimized regional coverage by national systems.
    - Maximize global coverage
    - Shorten repeat cycles
    - Increase cloud free data over cloudy areas

User Recommendations (cont.)

- Data Acquisition (cont.)
  - Develop a joint "data gap" acquisition strategy to minimize impacts on global data coverage from loss of one or more mid-resolution systems.
  - Jointly define a suite of environmentally sensitive sites, geohazard sites, calibration sites, and other key sites, and then develop cooperative strategies to ensure regular collection by all mid-resolution systems.
- Ground Segment Operations
  - Cooperate in the definition of common processing parameters to provide users with data in standard formats and projections, as well as standard metadata content.
  - Consider development of a common orthorectified image product for all mid-resolution LSI satellite systems.

Constellation Standards: Mid-Resolution Systems

- The primary objective was to define a suite of initial standards (or guidelines) that describe optimal characteristics of a mid-resolution LSI Constellation.
  - Space segments
  - Ground systems
  - Policies and operational considerations
- Standards were developed based on the compilation of a representative cross-section of user information and technical requirements.
- Work on this goal was accomplished largely via a contract let by the USGS with Noblis, a non-profit science, technology, and strategy organization.

From User Information Requirements to System Requirements

	Vegetation (Cultivated) Crops, Trees, Shrubs, Aquatic-Regularly Flooded	**Vegetation (Natural)** Forests, Shrubs, Grassland	**Infrastructure (Man-made)** Urban Areas, Roads, Other Structures	**Solid Earth** Rocks/Soils Topography	**Water Availability** Waterbodies, Snow, Ice	**Geo-Hazards** Forest Fires, Volcanoes, Floods
Spectral Band Coverage	Mapping/ Characterization Visible, NIR, SWIR* (IGOL 4.6.1, par. 1)	Ecosystem Function Hyperspectral (Decadal, pg 7-11)	Urban Mapping / Growth Tracking Landsat, SPOT bands, SAR (IGOL 4.8.2)	Surface Composition Hyperspectral, TIR (Decadal, pg 8-21)	Snow Amount Estimation Optical, thermal, and microwave (IGOL 4.6.1, par. 2)	Rapid Post-Burn and Agricultural Flooding Assessment Visible, Infrared, and Microwave (IGOL 4.4.1.1, par 4 and 4.6.1, par. 2)
Radiometric Accuracy	3% Goal/5% Threshold (Sentinel-2, par 3.11) <5% (NLIP, pg 33) (Landsat User Survey, pg 24)	3% Goal/5% Threshold (Sentinel-2, par 3.11) <5% (NLIP, pg 33) (Landsat User Survey, pg 24)	<5% (NLIP, pg 33) (Landsat User Survey, pg 24)	<5% (NLIP, pg 33) (Landsat User Survey, pg 24)	<5% (NLIP, pg 33) (Landsat User Survey, pg 24)	<5% (NLIP, pg 33) (Landsat User Survey, pg 24)
Spatial Resolution	Mapping/Monitoring Regional scale: 10m - 30m Global scale: 100m - 500m (IGOL 4.6.1, par.2)	GSE Forest Monitoring 10 meter Europe/other continents (Sentinel-2, par. 2.3)	GSE Risk/EOS Assets Mapping 5-10m (Sentinel-2, par 2,3)	Surface Composition 50-75m (Decadal, pg 8-21)	Seasonality and Intensity of Irrigation 10m - 30m (IGOL 4.9.4)	Rapid Post-Burn and Flood Assessment 10m - 30m (IGOL 4.4.1.1, par. 4) <20m (IGOL 4.4.3.5) 5-10m (Sentinel-2, par 2.3)
Geolocation Accuracy	<65m uncertainty (NLIP, pag 33)	<65m uncertainty (NLIP, pag 33)	<65m uncertainty (NLIP, pag 33)	<65m uncertainty (NLIP, pag 33)	<65m uncertainty (NLIP, pag 33)	<65m uncertainty (NLIP, pag 33)
Desired Repeat Frequency	Mapping / Monitoring / Characterization 5-10 day return period, cloud-free coverage (10m - 20m) (IGOL 4.6.6)	Ecosystem Function 30-day, or pointable to daily (Decadal, pg 7-11)	Human Settlement "Footprints" Update at or near annual increment (IGOL 4.8.1, par.1)	Surface Composition 30-day, pointable to daily (Decadal, pg 8-21)	Irrigated Area Observation Biannual ("moderate" res.) - Decadal ("fine" res.) (IGOL 4.9.1.1, par. 2)	Rapid Post-Burn Assessment Within 48 hr. of fire (IGOL 4.4.1.1, par. 4)

Preliminary Guidelines for Mid-Res. LSI Satellite Systems (example)

		Minimum	Recommended
Space Segment	**Spectral Band Coverage**	3 VNIR, 1 SWIR	≥4 VNIR, ≥2 SWIR, ≥2 TIR 2 Atm correction
	Radiometric Accuracy	<15 %	<5%
	Spatial Resolution	10-100m	10 to15m
	Geolocation Accuracy	500m	50 m
	Geographic Coverage (swath)	Not less than 60km	100 to 200 km
Ground Segment	**Desired Global Repeat**	4 Days (Constellation)	2 days (Constellation)
	Processing Level Provided	L1B	L1B-Orthorectified, L0 with Metadata, and other derived information products TBD
	Plans to Archive Data	3 months at local direct downlink station	Permanently by each participating satellite provider
	Search/Order Method	On-Line (Internet)	Through GEO Web Portal
	Metadata/Formatting Stds.	KML and JPEG2000	KML, JPEG2000, GEOTIFF, HDF, NetCDF
	Product Delivery Method	Internet	Internet, DVD
Data & Ops Policies	**Data Use Restrictions**	Minimal, consistent with pricing policy	None, consistent with national law
	Distribution Policies (includes pricing)	Tiered, with some free for education and research	Free (or nearly so) to virtually all
	Acquisition Strategy	Bilateral agreements between satellite operators and local downlink station holders	Global, based on an international LTAP strategy with some opportunities for user data acquisition requests
	General	Standard product and metadata availability	Standard products, metadata, algorithms

Data for a *Fundamental Climate Data Record*

- The objective of this 2007 goal was to demonstrate the value and viability of the LSI constellation by making a tangible contribution that both advances science and benefits society.
- The goal for 2007 was to provide the UN FAO Forest Resource Assessment 2010 (FRA2010) with the land surface image **data** needed to complete this assessment, or at least to establish the interagency agreements to do so.
- However, the FRA2010 Project was not able to identify holes in the primary Landsat data set, and thus exact data requirements could not be defined.
- Instead, estimates of the maximum number of image cells needed were made, and an agreement drafted calling for CEOS agencies to provide FRA2010 up to 1000 such image cells free of charge.

LSI Constellation – Next Steps and Challenges

- Key Planned Activities
  - Hold Study Team meeting in February.
    - Assess 2007 accomplishments and shortcomings
    - Engage in longer-term strategic planning
    - Develop 2008 Work Plan
  - Continue to work on unfinished tasks from 2007 Work Plan.
  - Enhance relevancy to GEO/GEOSS goals and objectives.
- Key Challenges
  - Dedicating sufficient personnel resources to accomplish the work.
  - Securing agency concurrence on documents approved by Study Team.
  - Fully engaging the land remote sensing user community.
  - Balancing agency agendas with common goals.
  - Managing expectations, such as what reasonably can be achieved and in what timeframe.

LSI Constellation Connections to GEO

SBA	Science and Measurements	GEO 2007-2009 Work Plan	GEOSS 2-year Targets	GEOSS 6-year Targets	GEOSS 10-year Targets
Disaster	**Fires**: fuels mapping, thermal mapping, recovery monitoring **Volcanoes:** deformation detection & monitoring; thermal monitoring **Floods:** topography; inundation monitoring **General:** pre-event conditions; post-event monitoring	DI-06-03: Integration of InSAR Technology DI-06-07: Multi-hazard Zonation and Maps DI-06-08: Multi-hazard Approach Definition and Progressive Implementation DI-06-09: Use of Satellites for Risk Management DI-06-13: Implementation of a Fire Warning System at Global Level DI-07-01: Risk Management for Floods	Strengthen International Charter. InSAR integration to disaster warning & prediction systems.	CEOS-assured continuity of critical observations. Explore Lidar/InSAR topography for low-relief & coastal zones. More automated satellite data processing systems for rapid hazard detection (oil spill, fires).	Address unmet needs: Significant increase in SAR (C/X/L); optimized L-band SAR for InSAR & forests; hyper-spectral for smoke & pollution plumes; passive microwave for soil moisture. Develop methods to determine shallow bathymetry (tsunami applications).
Health	**Infectious Disease:** land cover; topography; drainage basin flows **Accidental Death & Injury:** land cover; topography **Birth Defects:** land cover; topography	HE-06-03: Forecast Health Hazards HE-07-01: Strengthen Observation & Information Systems for Health HE-07-02: Environment & Health Monitoring and Modeling HE-07-03: Integrated Atmospheric Pollution Monitoring, Modeling & Forecasting	Define high-resolution sensors for health observations. Improve access to historical remote sensing data for health applications. Define observation & data requirements.	Derive wide-area health parameters from satellite. Specifications for major new observation capabilities.	Facilitate early detection and control of environmental risks.
Energy	**Oil & Gas Exploration, Refining & Transport Operations, Renewable Energy & Plant Siting Operations., Biomass Crop Optimization :** DEMs; land use/cover; geologic maps; urban extent; subsidence maps	EN-06-04: Using New Observation Systems for Energy EN-07-01: Management of Energy Sources EN-07-02: Energy Environmental Impact Monitoring EN-07-03: Energy Policy Planning	Develop strategic plan to use new generation systems. Exchange and use of data & products.	Exchange and use of data & products.	Implement operational observation system - reliable & timely data for energy sector. Exchange and use of data & products.
Climate	**Understanding, Assessing and Predicting Climate Change:** lake levels, snow cover, glaciers & ice caps, albedo, land cover, FAPAR, LAI, biomass, fire disturbance **Mitigating Climate Change:** fire disturbance, albedo biomass, land cover, FAPAR	CL-06-01: Sustained Reprocessing/ Reanalysis Efforts CL-06-02: Key Climate Data from Satellite Systems CL-06-03: Key Terrestrial Observations for Climate CL-06-05: GEOS IPY Contribution CL-07-01: Seamless Weather and Climate Prediction System	Implement GCOS-IP and IGOS Theme Reports. Emphasize importance of satellite observations for climate. Establish strong international coordination mechanisms.	Implement GCOS-IP and IGOS Theme Reports. Promote collaboration between observation and research organizations. Develop and operate new instruments for essential climate variable (ECVs).	Implement GCOS-IP and IGOS Theme Reports. Develop a long-term strategy for observation, data assimilation, and modeling.

LSI Constellation Connections to GEO

SBA	Science and Measurements	GEO 2007-2009 Work Plan	GEOSS 2-year Targets	GEOSS 6-year Targets	GEOSS 10-year Targets
Water	**Water Flux & Storage Information:** evapotranspiration; lake & reservoir extent/level; snow cover, glaciers, ice cap **Radiation & Energy Budget:** albedo; surface emissivity & temperature **Other Information:** topography, vegetation type; land use/land change	WA-06-02: Forecast Models for Drought & Water Resource Management WA-07-01: Global Water Quality Monitoring WA-07-02: Satellite Water Quantity Measurements & Integration with In-situ Data	Collaborative mechanism between observations and research communities.	Collaborative mechanism between observations and research communities.	
Ecosystems	**Ecosystem Extent, Composition, Structure, & Function:** habitat types; LAI; biomass; canopy **Human Drivers:** harvest intensity; lake eutrophic zones **Disturbance:** burned areas; pest & disease outbreaks; river discharge patterns	EC-06-01: Integrated Global Carbon Observation (IGCO) EC-06-02: Ecosystem Classification EC-06-07: Regional Networks for Ecosystems EC-07-01: Global Ecosystem Observation & Monitoring Network	Implement IGOS Carbon observing system. Continuity of moderate to high-resolution EO satellites for land cover. Study new sensors and platforms.	Global ecosystem mapping at 500m resolution. Establish the role of satellite data in global farming systems database. Continuity of high-resolution imagery for monitoring logging in key biologically diverse regions.	Monitoring of urban ecosystems.
Agriculture	**Food Security:** crop area; crop condition; crop yield **Timber, Fuel, & Fiber:** burned area, topography, forest area **Grazing Systems:** rangeland area; topography; land quality	AG-06-01: GEOSS Agriculture Strategic Plan AG-06-02: Data Utilization in Aquaculture AG-06-03: Forest Mapping & Monitoring AG-07-01: Improving Measurements of Biomass AG-07-02: Agriculture Risk Management AG-07-03: Operational Agricultural Monitoring System	Land cover mapping of 1:1M. Establish basis for continuity of high-resolution optical and radar satellites.	Global land cover product at 1:500,000.	Global production capabilities: Land cover observations for 1:250,000; Land use observations for 1:500,000. Fully integrated observation system for on-time drought Early Warning System for food-insecure regions.
Biodiversity	**Conservation:** location and area of ecosystems **Invasive Species:** vegetation type; vegetation stress; impact extent **Natural Resources:** land cover; topography; vegetation stress	BI-06-03: Capturing Historical Biodiversity Data BI-07-01: Biodiversity Observation Network BI-07-02: Invasive Species Monitoring System	Develop observation strategies to support 2010 Convention on Biological Diversity (CBD) targets.		

A Potential *Real* Prototype
Land Surface Imaging Constellation